

throat of the corolla, manifestly below the orifice: in anthesis they do not show at all; later they may slightly project. According to Seemann's figure the "not quite ripe" capsule is ovoid and slightly longer than the calyx. This figure accords well with the specimens from coll. Wright, of Arakamtchetchene Island, Behring Strait; from Arctic Alaska, Muir; and Lake Lindeman at the head of the Yukon, Lieut. Schwatka. Originals from Chamisso, and part of those from St. Lawrence Bay, Eschscholtz, are similar but smaller.

Var. DENTATUM. Larger: leaves with blade from one or two to three or nearly four inches long (in the dried specimens thin), oval or ovate to oblong, commonly repand or sparingly dentate, at base abruptly or truncately contracted into long and wing-margined petioles: scapes a span to a foot high, 2-7-flowered: corolla so far as known white: capsule globular- to oblong-ovoid, moderately surpassing the ovate or triangular-acuminate calyx-lobes, half-5-valved.—*D. dentatum* Hook. Fl. i. 119. *D. Meadia*, var. *frigidum* Watson, Bot. King Exp. partly. *D. Meadia*, var. *latilobum* Gray, Syn. Fl. l. c. The "N. W. Interior, Douglas" is probably interior of Oregon. Lyall collected it in 1850 on the east sides of the Cascade Mountains in Washington Terr.; Brandegee in the same region in open woods in 1883; Suksdorf in 1885, at the foot of a waterfall near Bridal Veil in N. E. Oregon; Henderson in 1884 and 1885 on wet rocks, along bluffs of the Willamette; Howell near the Cascades in 1886. The most southern and remote station is that of Watson in the Wahsatch Mountains, Utah, at the head of Cottonwood Cañon. It has all the essential characters of *D. frigidum*, but is much larger.

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### The Development of the Gymnosporangia of the United States.\*

W. G. FARLOW.

The study of the connection between the different forms of Gymnosporangium and Roestelia known in the United States has not been by any means as simple as the similar study in Europe. This is owing, perhaps, to the fact that we have about double the number of species found in Europe, and it has not always been easy to determine exactly which of our forms were the same as those of Europe, or even clearly to define our own species. Before one could begin to study the connection between the Gymnosporangia and Roesteliæ, it was necessary to have a compara-

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tively clear notion of the species as distinguishable by their gross and microscopic appearances, for, until that was the case, any account of cultures made would be quite unintelligible. Nor could we hastily assume that those of our *Gymnosporangia*, which appear to be very much like European species, must have the same *Roestelia* form as in Europe. Practical experiment by cultures is the only method of settling the question effectually. If the anatomical characters are the same, and if the sowings of the spores are followed by the same *Roestelia* in both cases, then our form and the European belong to the same species, otherwise not.

In a paper published in 1880, I attempted to take the first step by collating what had been written about our species and supplementing it by observations on a large amount of living and herbarium material, so as to be able to form an estimate of the comparative distribution of both our *Gymnosporangia* and *Roesteliæ*, and, as far as our knowledge then allowed, to learn something of the probabilities of the connection between different forms; for we must naturally assume that, if there is any natural connection between *Gymnosporangia* and *Roesteliæ*, the connected forms will be found growing near together rather than separated by long distances.

In the paper mentioned I also gave an account of some cultures of *Gymnosporangium* spores on different hosts for the purpose of finding out what *Roesteliæ* followed the sowings. Although spermogonia in abundance followed some of the sowings, the æcidia themselves did not develop, and hence it was impossible to be sure of the species, although one could perhaps infer something. In northern and central Europe where the species of *Roestelia* are by no means as numerous as with us, some botanists who, on sowing *Gymnosporangium* spores, have obtained only spermogonia have at once assumed that they belonged to the *Roestelia* growing on the same host in nature.

This assumption, somewhat dangerous it must be admitted, might perhaps be allowed in Europe where the species are few, but would be quite unwarranted in this country where not only do most of our *Roesteliæ* grow on several different hosts but, in several cases, the same host is known to support several different forms of *Roestelia*. Although my cultures were not conclusive at all, taken in connection with what was known of the comparative natural distribution of the forms in question, they afforded, in a measure, some guide to the direction in which we might expect more definite information in the future.

Since 1880 my cultures have been continued at intervals, without, however, the production of æcidia, and in the meanwhile



our knowledge of the natural distribution of the species has been enlarged and emended in several respects. In the present connection I wish to speak only of the forms found east of the Rocky Mountains, of which the enumeration given in 1880 is still correct with one exception. There is to be added one species from the Rocky Mts., but it can not enter into the present discussion. Of the different notices on the subject which have appeared since 1880, I need refer only to a paper in the Proceedings of the Am. Academy of Arts and Sciences, issued in Feb., 1885, in which, after summing up all the evidence to be obtained from my numerous cultures and what was known of the distribution, I came to the conclusion that: first, *Gymn. biseptatum* Ellis, and *Roestelia botryapites* Schweinitz were probably connected; secondly, that *Gymn. globosum* Farlow might possibly be connected with *R. aurantiaca* Peck; thirdly, that *Gymn. macropus* Lk. has as its *Roestelia* a form growing on apples and Amelanchier.

Last spring cultures of several species of *Gymnosporangium* were made by Mr. Roland Thaxter, a student in the cryptogamic laboratory at Harvard, and the results which he has obtained are of great interest. The details will be given in a paper by Mr. Thaxter and I should like, in this connection, to call attention to some of the principal results reached. To start with the simplest case. The cultures of the spores of *Gymn. biseptatum* on two plants of Amelanchier were followed by spermogonia in ten days and later the æcidia began to form on the under surface of the leaves. Although the peridia are not yet ripe there can be no doubt that the species is *R. botryapites*, as the tubercular swellings produced can not be mistaken for those of any other species known in this country. Furthermore, in the cultures as in nature this *Roestelia* has developed very slowly, and it is highly probable that the æcidia will ripen as, when growing wild, the tubercles appear in July and August, but the ripe peridia are not found until some time in September, in Massachusetts. This case affords then a confirmation of the first statement mentioned above.

My second supposition has been proved by Mr. Thaxter's cultures to be incorrect. The spores of *Gymn. clavipes* growing on *Juniperus Virginiana* were followed by spermogonia in ten days when sown on Amelanchier and apples, and in about a month were followed by ripe æcidia on the stems of Amelanchier. This culture was the most striking of any. The æcidia were luxuriantly developed and the species was seen to be without doubt *R. aurantiaca*. In this culture furthermore the spermogonia appeared principally on the leaves while the æcidia were on the



stems, and this is known to be the case when the species grows wild. On apple only *spermogonia* appeared, but it is well known that the species not unfrequently grows on apples. It might be asked whether the result of this culture is not at variance with what is known of the distribution of *Gym. clavipes* and *R. aurantiaca*? The last named species is known to have a wide range but it has been believed that the *Gymnosporangium* was confined to the eastern parts of the country where it is not so common as some other species. That it is more common in the East than has been supposed is shown by the fact that it was found on *Juniperus communis* at Weymouth, Mass., by Mr. J. E. Humphrey last spring, and abundantly on the same host at Kittery, Me., by Mr. Thaxter. On *J. communis* the fungus is more easily recognized than on *J. Virginiana*. On both hosts it is generally found on the stems and is recognized by the reddish color, rather than the brown or yellow found in other species. The pedicels are much inflated at the top and the spores quickly fall from the pedicels and germinate almost invariably at both extremities. With this I had confounded a foliicolous form very common on *J. Virginiana* near Cambridge, which produces the birds-nest distortions. The fungus as in this case is rather brown than red, but the pedicels are often much swollen at the tip, and the spores in some cases germinate at the two extremities. If in this form the pedicels are sometimes quite as much swollen as in *Gym. clavipes*, it should be said that sometimes they are not much swollen and while in *Gym. clavipes* the germination is almost invariably at both extremities in the foliicolous form under consideration the germination is only occasionally so, as I find by repeated experiments. The near relationship of *G. clavipes* to *G. conicum* was pointed out in my first paper. I now think that the true *G. clavipes* is specifically distinct from the foliicolous form which produces the birds-nests, and the latter form, together with a stem form, should be referred to *Gymn. conicum*. But to return to the true *Gymn. clavipes* as it grows on stems. It must be admitted that, so far as we yet know, the *Roestelia aurantiaca* extends much farther west and south than the *Gymnosporangium* with which from Mr. Thaxter's cultures it appears to be connected. It should not be forgotten, however, that the *Roestelia* is the most striking of the genus and is found on common cultivated plants, whereas the *Gymnosporangium* usually grows in company with the much more conspicuous *G. macropus* and *G. globosum*, and is much more likely to escape observation. Now that we know that it occurs on *J. communis* as well



as J. Virginiana botanists may, perhaps, discover the species in regions where it is not now known.

Taking next the form which grows on Juniperus Virginiana and produces the well known birds-nest distortions, sowings were made on Pyrus Americana, apple, Amelanchier, and Pyrus arbutifolia and spermogonia appeared in great abundance on Amelanchier in seven days and on one apple in eight days and in a month æcidia developed on Amelanchier. The species was *R. cornuta* which is considered in Europe to belong to *Gymn. conicum*. Why the æcidia did not also develop on Pyrus Americana, the host on which *R. cornuta* occurs in its most marked form in this country, is a question. The failure in the present case may be merely an accident and future cultures may succeed. At any rate, the experiments should be repeated several times before we conclude that the spores of the birds-nest form will not grow on Pyrus Americana. Considering the distribution, the result of the cultures, and in general the anatomical structure, I think that it is most probable that the species is *Gymn. conicum* which Oersted concluded from his cultures to be connected with *Roestelia cornuta*. We must, however, ask one question. In Europe this species grows on Juniperus communis and, if our form on J. Virginiana is really the same, how does it happen that in this country the species is entirely unknown on J. communis which frequently grows in fields with J. Virginiana? I know one small field in which the two junipers grow mixed together, and although I have watched for years I have never found any *Gymnosporangium* on the J. communis there although the *Gym. conicum* so-called is abundant on the J. Virginiana.

Cultures were also made of the spores of *Gym. clavariæforme*, a species which grows on J. communis, and has apparently been more abundant this year than usual. Although sown on Pyrus Americana, apples, and Cratægus they only grew on the Cratægus where they produced *Roestelia lacerata*, the æcidium which in Europe is believed to be connected with the same species. In general the distribution of the *Gymnosporangium* and the *Roestelia* is about the same in the north and west, although the latter is much more common and is found in places not very near juniper trees.

*Gymnosporangium Ellisii* is, for some reason or other, less easily cultivated than the other species. In my cultures no results were obtained. In Mr. Thaxter's cultures when sown on Pyrus arbutifolia the spores seemed to cause spots on the leaves but no spermogonia or æcidia developed. It may be possible that the species is connected with *Roestelia transformans* which occurs on the Pyrus.



There remains to be considered two species, *Gymn. macropus* and *Gymn. globosum*, sometimes considered a form of *Gymn. fuscum*. The two species occur on *J. Virginiana*, often together, and are the most striking as well as probably the most common species east of the Mississippi. One would naturally expect that the study of their development would not be difficult. Unfortunately, however, *Gymn. globosum* is as great a puzzle as ever. In all my cultures this species was the one which always produced the greatest crops of spermogonia. Sometimes they were so abundant as nearly to cover the young plants used for experiments which in some cases soon died, apparently killed by the excessive growth of the fungus. Although spermogonia appeared on several species of *Cratægus* and on apples, in no case was there the least sign of æcidia. The fungus flourished for a few weeks and then the leaves either dropped off or recovered their normal appearance. Mr. Thaxter has had precisely the same experience except that he also found spermogonia on *Pyrus Americana*, a host which I had not tried in this case. He had the same luxuriant growth of spermogonia on *Cratægus* but no trace of æcidia. No explanation can be offered for the failure to obtain æcidia for, at first sight, the conditions seem more favorable than in any other species. Nor is it possible from the distribution to guess with what *Roestelia* it is connected if we exclude *R. aurantiaca* which, as we have seen, followed the sowings of the spores of *Gymn. clavipes*. It is out of the question to consider *Gymn. globosum* and *Gymn. clavipes* as forms of one species both from their habit, microscopic structure, and the distortions produced. The species to which it appears to be most closely related and with which it is even identified by some writers is *Gymn. fuscum*, a species which is considered by European botanists to have for its æcidium *Roestelia cancellata* which grows on *Pyrus communis*. Now although in this country one often finds pear trees growing close to red cedars attacked by *Gymn. globosum* there is not a single undoubted instance of the occurrence of *Roestelia cancellata* in this country and the few herbarium specimens bearing that name are more than doubtful. *R. cancellata* is one of the most easily recognized forms and it is hardly credible that it has escaped the observation of our botanists unless it is very rare indeed while *Gymn. globosum* is very common.

With regard to *Gymn. macropus* we have more definite information, although here, unfortunately, the case is not quite clear. This species has been studied more than any other, not only on account of its great size and abundance, but also on ac-



count of its supposed relation to diseases of apple trees. My cultures seemed to point to a connection with some common *Roestelia* on apples, and, I suspected, judging by what I had seen in orchards near infected cedars, that it might be the minute form generally considered a variety of *R. lacerata*, which is very common in the east. In my cultures I found only spermogonia. During the past spring cultures were made by Prof. B. D. Halsted, at Ames, Iowa, and by Mr. Thaxter, at Cambridge, and I found an instructive case at New London, Ct., to which I will refer later. Many have probably read the account of Prof. Halsted's experiment, in a recent number of the *BOTANICAL GAZETTE*, and, with the author's consent, I will state briefly the result. Early in the season, specimens of *Gymn. macropus* were gathered and allowed to develop under cover, so that there need be no danger of mixture with spores from outside. The germinating spores were then sown on the young leaves of a wild crab apple, *Pyrus coronaria*. The leaves and tips of the branches sown were then covered with small bags, and about three weeks later there appeared an abundance of spermogonia. The experiment was repeated on other twigs with a similar result later, and in both cases the fungus had developed to a marked degree before there was any trace of spots caused by natural infection on parts of the tree which had not been covered. In time the æcidia appeared and proved to be what has usually been called *Roestelia penicillata*.

To turn for a moment to Mr. Thaxter's cultures. The spores of *Gymn. macropus* were sown on *Pyrus Americana*, *Crataegus coccinea*, apples, *Amelanchier*, and *Pyrus arbutifolia*, but spermogonia appeared only on the apples. The cultures were continued and on July 14 a small number of æcidia appeared and grew slowly. Unfortunately, the æcidia have remained small, and the determination can not be made with certainty, but it must be admitted that they give one the impression rather of the small form of *lacerata* than of *penicillata*. It may be added that the wild specimens of *R. penicillata* had already developed at this time, and it is not probable that the æcidia in Mr. Thaxter's cultures were any later in developing than the wild form.

In the latter part of June I noticed at New London what might be called a natural culture of *Gymn. macropus* on a wild apple. A small *J. Virginiana* and a small apple had grown together in such a way that they seemed to form but one tree. My attention was first attracted by the immense number of bulbs of the *Gymn. macropus* on the cedar. They were so numerous as to make it look like a decorated Christmas tree. I had never seen a cedar so covered with the *Gymnosporangium* and at the



same time the apple was yellow with the spermogonia of a *Roeselia*, at the time immature, but which afterward developed into a form of *R. penicillata*. It might be asked why, judging from Prof. Halsted's culture and the New London specimens, we should not consider the *R. penicillata* to be the æcidium of *Gymn. macropus*, for Mr. Thaxter's culture, while it seems to point to a different conclusion, is not sufficient in itself. If we look at the opinions of European botanists we find that they differ very much with regard to *R. penicillata*. On anatomical grounds alone, some regard it as merely a form of *R. lacerata*. Others, like Winter, think it distinct. From their cultures, also, they have not reached a definite conclusion; for, while Oersted thinks that *R. penicillata* is the æcidium of *G. clavariæforme*, Rathay maintains that it is a form of *Gym. conicum*. Oersted considered that he obtained both *R. lacerata* and *R. penicillata* from sowing the spores of *Gymn. clavariæforme* on *Cratægus* and apples respectively, but it is claimed that he never really obtained the æcidia on apples but inferred that the spermogonia on apples must belong to *R. penicillata*. But such an inference is not strictly logical. In American cultures *Gymn. clavariæforme* was followed only by *R. lacerata* not by *R. penicillata* which is in confirmation of the views of those who are opposed to Oersted's conclusion. In other words, the undoubted *Gymn. clavariæforme* on *J. communis* in this country acts when sown just as that species is said by the opponents of Oersted's view to act in Europe. If we accept Oersted's view we must accept the view that *Gymn. macropus* of this country is only a form of *Gym. clavariæforme* which grows on *J. Virginiana*. This is the view of Schroeter, but it is difficult for botanists in this country, who have seen both species growing, to regard them as forms of a single species. It may be true, however, and the important point for our botanists to settle is, can the spores of *R. penicillata* be made to grow on both *J. communis* and *J. Virginiana* and produce on the former what we now call *Gymn. clavariæforme*, and on the latter what we call *Gymn. macropus*.

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### The Theory of Immunity from Contagious Diseases.\*

D. E. SALMON.

The immunity which an individual acquires from the effects of a contagion, by passing through one attack of the disease which it causes, has never been completely and satisfactorily ex-

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